PSYCHE.

THE SCALES OF COLEOPTERA.

BY GEORGE DIMMOCK, CAMBRIDGE, MASS.

(*Continued from page 47.*)

GENERAL SUMMARY.

After the preceding descriptions of some forms of scales among coleoptera, I wish to consider the subject more generally. First to be considered is the question, in what families of coleoptera have scales been found. Fischer mentioned scales as occurring in *teredyles*, *clavicornes*, *lamellicornes* and *curculionides*,—or to use the modern equivalents for the families in which he found scale-bearing species,— in the *cleridae*, *ptinidae*, *dermestidae*, *byrrhidae*, *scarabaeidae* and *curculionidae*. To this list I would add with certainty the *elateridae*, basing this addition on the scales of *Chalcolepidius* and *Alaus* described in this paper. According to my views of what constitutes a scale I would add further the *cerambycidae*, and with some doubt the *buprestidae*. The scales of *Clytus robiniae* described in this paper, it seems to me, can scarcely be called hairs, altho to the naked eye or to a low-power lens they appear like hairs. They are too much flattened and the striae end in the manner in which they do in scales. The question whether the sword-shaped appendages of *Psiloptera drummondi* are really scales or hairs is less easily settled but I should be inclined, from the arrangement of their striae, to term them scales. The form of scale from *Alaus* is readily seen, by the figure of its transverse section (fig. 7, *d*), to be too flat to be termed a hair, and this or similar forms are not uncommon among coleoptera.

The question of the morphological identity of scales and hairs of insects has been long since settled, so that the question of whether an appendage is a scale or hair has little importance. The extremely minute spines or hairs upon the wings of diptera, hymenoptera and other insects are simply another form of scales. It is only in insects where certain kinds of brilliant coloration have been developed that one finds scales. This leads to a consideration of how hairs and scales of insects affect coloration. They may simply cover a surface of the same color as their own; in such cases hairs may, according to the angle in which they stand, their abundance or their length, give rise to appearances which we designate as pubescent, velvety, pilose, sericeous, etc.; scales under similar circumstances may give rise to similar appearances, but are most often imbricated and usually cause more lustre than hairs. Hairs or scales may be of a different color from the surface on which they are placed. If they are numerous and opake they may entirely conceal the surface on which they are inserted, as the white hairs hide the bronze surface of the sides of the thorax in *Cicindela dorsalis*, and as the white scales of *Alaus oculatus* hide the black surface beneath the rings on the thorax; or they may only partly conceal the surface of the insect, giving rise to coarser and finer mixtures and shades of color. Opake scales, or hairs, of more than one color, may cause figuration, whether they imbricate as on the wings of lepidoptera, or are separated as on *Anthrenus scrophulariae*.

The possibilities of varying effects of color are many with opake scales and hairs, but with transparent ones, especially if they are colored, the effects of color can be multiplied still further. With hairs the effects are not so remarkable as with scales. The scale, by its form, increases the number of layers of the surface of an insect which are available for colorational purposes. Where the surface of an elytron had previously a cuticular and hypodermal layer, by the addition of a scale of the simplest type there is an addition of two cuticular and, theoretically at least, two hypodermal or sub-cuticular layers; in all six layers, without counting overlappings of imbricated scales. Some of these surfaces may have pigments, striae, hairs and other appliances to produce colors, and other surfaces may have other striae and contrivances to act on the colors produced. The numerous modifications need not be enumerated here. I have alluded to special effects of coloration in describing the scales of different insects and shall again refer to some of them when discussing the modes by which the scales themselves are colored. I may add here that the general effect of transparent scales is to produce metallic coloration.

The kinds of coloration in coleoptera have been neatly tabulated by Fischer, according to the families of these insects. I translate his table, making in it, a few alterations based upon my own observations and indicated by italics. (*See next page.*)

Next to the consideration of how the color and presence of scales and hairs affect the appearance of surfaces to which they are attached is the not less interesting question of the causes of coloration in scales themselves. But before considering the causes of color, properly speaking, a few words are appropriate on the causes which produce silvery and milk-white appearances in scales and on insects. Leydig was the first, in 1855, to call attention to the presence of air between or beneath their chitin layers as a cause for certain silvery spots and scales on insects. He speaks of air in the finer pore-canals of *Ixodes testudinis*, giving these canals a black appearance, but causing the whitish grey color of the skin. So too he mentions silvery scales on a spider, *Salticus*, and glistening hairs on another spider, *Clubione*

	COLORS		COLORS					
				By special epidermal structures such as				
	One	Several	In the substance	Hairs	Scales	Forming designs	Metallic lustre	Surface hairy [1]
Carabici	Commonly	More rarely	Always	*Sometimes*	Never	Not rarely	Very often	Rarely
Hydrocanthari	More rarely	Commonly	"	Never	"	" "	Very rarely	"
Brachelytrini	Commonly	"	Usually	Rarely	"	Not commonly	Not rarely	Commonly
Sternoxi	More rarely	"	"	"	*Sometimes*	Commonly	Commonly	"
Malacodermatici	" "	"	Always	Never	Never	Not commonly	"	"
Teredyles	Commonly	"	Sometimes	Sometimes	Rarely	Not rarely	Very rarely	"
Clavicornes	"	Very commonly	Usually	Commonly	"	Very commonly	Not commonly	"
Palpicornes	"	Rarely	Always	Never	Never	Rarely	" "	Rarely
Lamellicornes	More rarely	Commonly	Usually	Rarely	Often	Commonly	Very many	Commonly
Melanosomatici	Always	Never	———	———	———	———	Never	Never
Taxiceratici	Commonly	More rarely	Always	Never	Never	Rarely	Very rarely	Rarely
Tenebrionini	"	" "	"	"	"	"	" "	"
Helopii	More rarely	Commonly	"	"	"	"	Rarely	Very rarely
Trachelini	" "	"	Almost always	Rarely	"	Not rarely	Never	Commonly
Vesicantes	Usually	Very rarely	Always	Never	"	Very rarely	Usually	Rarely
Stenelytrini	Commonly	More rarely	"	"	"	Not rarely	Commonly	"
Curculionides	Rarely	Usually	Rarely	Commonly	Very commonly	Very commonly	"	Commonly
Xylophagi	Usually	Rarely	Always	Never	Never	Not rarely	Never	"
Longicornes	Rarely	Usually	Commonly	Commonly	*Sometimes*	Very commonly	Very rarely	Usually
Chrysomelini	Commonly	More commonly	*Usually*	*Rarely*	Never	" "	Very commonly	Very rarely
Erotylini	"	Commonly	Always	Never	"	Rarely	Very rarely	Rarely
Coccinellini	Rarely	Usually	"	"	"	Usually	Never	"
Pselaphii	Commonly	Commonly	"	"	"	Never	"	Commonly

[1] Without regard to coloration or figuration.

claustraria, which appendages owe their silvery whiteness to air within them. Again he mentions hairs which contain air on spiders of the genera *Epeira* and *Theridium*. Then further, when considering the insects, Leydig writes that it is not difficult to see that the silvery under surface of *Hydrometra paludum* is due to the pore-canals being filled with air. He goes on to say "In a similar way the wings of *Notonecta glauca* seem to enclose air, and I suspect also that the white color of the hairy powder of many *aphidae* and *coccidae* is brought about by like causes." Further on he writes, "If one regards the color of scales it can inhere as diffuse material in the substance of the scale itself, or it appears under the form of molecular pigment, which is deposited in the cavities of the scales, or finally the cavities are filled with air which gives a snow-white appearance to the scale." Again Leydig writes that when Fischer says, in speaking of "granulation-scales" (i. e., such scales as those of *Hoplia trifasciata*), "that the 'upper or granulation layer' dissolved visibly in water, but quickly in alcohol or ether, and then only the 'striate basal layer' remained, the words show that he has certainly seen but incorrectly explained that change which the scale undergoes upon the loss of air, in so far as he assumed a 'granulation layer' which dissolves in water!"

Leydig accounted for silvery glistening scales and surfaces, and for milk-white coloration among insects, but he fails to account for the difference between these two kinds of coloration. The white scales of *Pieris rapae* and the silvery scales on the under side of the posterior wings of *Argynnis idalia* both contain no appreciable coloring matter, and both contain air; both, too, are simply milk-white by transmitted light. The difference is that there must be in the silvery scales a polished surface towards the observer. Ground glass does not appear silvery, but what is the surface of the smoothest polished plate of glass but finely ground glass? Ground glass differs from polished glass only in degree: in ground glass the scratches are so coarse and so abundant as to turn most of the light-waves into the glass again, where they are lost. In polished glass the scratches are still present, but have become so small that even the waves of light are large in proportion to them, and so the light-waves reflect as if from a theoretically flat surface. But something more than a polished glass is needed to reflect much light, for most of the light passes through the glass; something non-transparent must be behind the glass. In the common mirror it is a mercury amalgam: in the butterfly's silvery scale it is a layer of cavities filled with air. This layer of cavities is not transparent for the same reason that ground glass is not. If we treat the scale with chloroform it has an analogous effect to that of treating the back of a common mirror with nitric acid, thus dissolving off the amalgam. In both cases a non-transparent body is converted into a transparent one, and a mirror, which, whatever be the materials of which it is made, if approximately perfect has a silvery appearance from the *amount* of reflected light, is reduced to a slightly reflecting surface. But let the scale dry again from its bath, as Fischer apparently did not do, and the mirror will again appear. Both silvery and milk-white colorations are then only optical effects produced by reflected light.

Still another kind of appearance is seen in the scales of *Hoplia* and of *Entimus*. These scales are brilliantly colored, yet their color is in the one case entirely lost, in the other case greatly changed by wetting with almost any liquid, but when redried the colors reappear with all their previous brilliancy. This coloration also resists all forms of bleaching. It must therefore be produced by some decomposition of light. Whatever acts upon the light must be within the scale, not upon the outside, for all those scales which remain perfectly sealed, so that the liquid does not enter them, retain their color even surrounded by liquid. This proves that the color is not due to external striation, where such exists. The finer striation of the scales of *Entimus* is evidently internal, from its relations to the differently colored internal cavities of the scales. Besides this striation the interior of the scale is evidently filled with a pith-like substance into which liquids enter with equal readiness in all directions; this pith-like portion apparently has some direct influence upon the production of the coloration, for wherever it is injured or has shrunk away from the basal end of a scale there is no longer coloration in that place. Perhaps it is a necessary filling to cause the striae to refract the light, the same as air-cavities are necessary as a backing to produce the silvery color in the scales of lepidoptera. The striae themselves are very fine, but whether they are the causes of color is hard to determine without more accurate instruments of measurement than I have at my command. As near as I could determine they are 0.0008 to 0.0009 mm. apart. The wave length of a ray of light from Frauenhofer's *A* line of the spectrum is, according to Willigen, .00076092 mm., and the wave length at the H_1 line is, according to the same authority, 0.00039713 mm.; the difference being 0.00036379 mm., or the difference of wave length between violet and red light. To determine the *place* in the spectrum to which the striae of these scales correspond would require, of course, much finer measurements.

The kinds of coloration of scales thus far described are what Hagen has termed "optical colors."

The second kind of coloration is what Hagen terms "natural colors," of which he distinguishes two kinds—dermal, where "the pigment is deposited in the form of very small nuclei in the cell, or in the product of cells, in the cuticula," and hypodermal, where "the pigment is a homogeneous fatty substance, a kind of dye somewhat condensed." Hagen further says "To a certain extent the dermal colors may have been derived from hypodermal colors, as the cuticula is secreted by the hypodermis, and the colors may have been changed by oxidation and air-tight seclusion." Like organic colors in general, I have found dermal as well as hypodermal colors to be subject to the chlorin bleaching processes, which I first applied, in 1875, for the purpose of studying the venation of lepidoptera,[39-40] the only difference being this, that dermal colors require to be freed, by long maceration, from their prison in the chitin.

Thus a distinction between dermal and hypodermal colors is that the former bleach only by destruction of the parts in which they are enclosed, the latter bleach readily. I do not wish to enter here into a prolonged discussion of the chemical reactions which are similar or alike in dermal and hypodermal colors, which I hope to discuss later, after more experiments, but will add a table which I think will serve for the separation, under the microscope, of the different kinds of coloration.

By this and other modes of separation I have studied all the scales of coleoptera which I had at my command, and

Treat dry scales with absolute or strong alcohol.

- Broken scales become colorless but regain original coloration if dried again . . . . — *Optical coloration.*
- Scales become more transparent (if injured), but retain some coloration. Add to the wet scales some chlorin-bleaching solution and
  - The color remains until the scales begin to macerate and lose their structural peculiarities
    - Washed with alcohol and redried all the undestroyed scales return to their original coloration. . . . . . — *Optical coloration.*
    - *Or*
      - Reflected light shows colors complementary to the original coloration . . . . — *Optical coloration.*
      - Reflected light shows same coloration as transmitted light . . . — *Dermal coloration.*
    - Washing with alcohol and redrying causes no further change of coloration. — *Dermal coloration.*
  - The color disappears, in at most an hour or two, and does not reappear by any subsequent treatment . . . . — *Hypodermal coloration.*

I have only found optical and dermal (never hypodermal) coloration; optical coloration being common. In the case of lepidoptera, optical coloration, except where concealed or subdued by hypodermal coloration, is somewhat rare, and I have never discovered scales where dermal coloration occurred. (This may occur in brilliant gold

[39]Dimmock, G. Bleaching the wings of lepidoptera. (Psyche, Sept. 1875, v. 1, p. 97-99.)

[40]Dimmock, G. A method of bleaching wings of lepidoptera, to facilitate the study of their venation. (Proc. Amer. assoc. advanc. sci., 1875, v. 24, p. 228-230.)

colored scales, such as some species of *Plusia* present, but I had none at hand to examine.)

I may here note an interesting object on which to try this mode of color-separation — this object is the head of a freshly killed larva of *Smerinthus*. Upon the application of strong alcohol the tubercles lose their milky whiteness from the loss of air, thus proving optical coloration. Chlorin bleaching-fluids rapidly destroy the green color of the fluids of the head, proving it to be hypodermal, while the outer chitin-shell, or covering of the head, resists all bleaching action, remaining green until it is macerated.

After what has been given already in the descriptive portion of this paper there is little to be said, based on my own work, in regard to the structure of scales. A point worthy of mention is perhaps this, that I have found but one insect having scales or hairs, in which these appendages did not contain more or less air. This insect is *Chalcolepidius*. The elytra themselves, in many cases where they are white (e.g., in *Cicindela dorsalis*), have spaces within them, besides the tracheae, reserved for air, as well as spaces for the fluids of the body. When so-called "blooms" are present, as upon the dorsal surface of the abdomen of some species of *Tabanus*, this bloom is often produced by very minute thin-walled hairs. Where very light colors, and white, whether milk-white or silvery-white, are present in insects, the existence of air beneath the cuticula is the rule.

I cannot yet wholly understand why the scales of lepidoptera discharge the air contained in them so much more readily, when subjected to treatment with alcohol and chloroform, than do the scales of coleoptera, while, on the other hand, water will drive out the air from scales of coleoptera much quicker than from scales of lepidoptera. There are several things which might cause these phenomena, but I am inclined to the opinion, without having *proved* its correctness, that their cause is the presence of more oil in the scales of lepidoptera than in those of coleoptera. This would concide with the greater lustre of lepidopterous scales, and with other points in their appearance. Perhaps the entrance of the shank of the scale is only closed with an oily mass, for I have never seen the scale of a lepidopteron resist entirely the entrance of fluid, as is often the case with the scales of coleoptera.

The striae upon scales of lepidoptera have long been a subject of investigation, but, as far as I know, no one, up to 1880, published the fact that their striae were upon the outside, or upon the side turned away from the wing. In Burgess' paper on *Danais*,[41] in that year, he figures transverse sections of the scales of that butterfly, and calls attention to the fact. Without having seen Burgess' paper, in the following year, I noticed that the striae upon the scales of the proboscis of *Culex* were on the outside, and so

[41] Burgess, E. Contributions to the anatomy of the milk-weed butterfly, *Danais archippus*. (Anniv. mem. Bost. soc. nat. hist., 1880.) Separate, p. 6, note, pl. 1, fig. 6 and 6*a*

figured them in my dissertation[42] and in *Psyche*.[43] By the transverse section of a scale of *Alaus*, figured in this paper, it will be seen that there too the striae are upon the outer surface. That I have found to be the case with the principal or external striae, in all beetle-scales which I have examined. It is, briefly expressed, only the development of a mechanical law, which extends to many surfaces which shrink by drying or cooling. It can be easily illustrated by partly filling a bladder with water and allowing it to dry upon a board. The main folds will be, of course, upon the exposed upper side, and the longitudinal ones will be the more prominent.

Another easy way to prove that the striae upon the scales of the wings of lepidoptera are upon the side away from the wing is to take impressions of the scales upon a surface of collodion. These impressions are readily taken by pressing quite lightly a dry butterfly's wing upon a microscope slide which has been moistened with a solution of collodion in ether. The wing should be removed before the collodion has become thoroughly dry, when beautiful impressions of the outer surface of the scales will remain on the collodion surface, and may be mounted for future study. A very little practice will enable one to remove the wing at the proper moment; if left too long the greater part of the scales will be removed from the wing and adhere to the collodion. In order to take impressions of the under sides of scales, the latter should be transferred, by a process described by Berge,[45] and later by H. Landois,[46] and others, to a piece of paper, and the impression on collodion then taken from these inverted scales. The process of transferring the scales to paper or other surfaces, first used to get prettily colored figures of butterflies, consists, leaving out details, in gumming the wing of a butterfly upon paper with gum arabic or glue, and, after thorough drying, removing the wing, leaving the scales attached to the paper. From such "butterfly pictures" impressions of the under surface of the scales can be readily taken.

By rubbing anilin colors into impressions of the striae of the scales of insects I hope later to gain further knowledge of the external configuration of insect scales.

Fischer, in his dissertation, mentioned that branching or notched hairs seemed a characteristic of the *scarabaeidae*, and I have only found them in that family of coleoptera, although, outside of coleoptera, they are not rare (e. g., in *Bombus* and other hymenoptera). Among the *scarabaeidae* this notching, or covering of the surface of the hairs with secondary hairs, extends also to the scales, and we have some that, like those of *Hoplia*, seen in fig. 3 *b* and *c* (p. 10), present the general appearance of cactus leaves.

[42]Dimmock, G. The anatomy of the mouth-parts and of the sucking apparatus of some diptera. Dissertation . . . Leipzig university . . . 1881. Pl. 1, fig. 8, 12–15.

[43]Dimmock, G. Anatomy of the mouth-parts and of the suctorial apparatus of *culex*. (Psyche, July-Sept. 1881 [7 March 1882], v. 3, p. 231–241, pl. 1.)

[45]Berge, T. Taschenbuch für käfer- und schmetterlingssammler . . . Stuttgart, 1847, p. 55–62.

[46]Landois, H. Neue methode schmetterlinge zu copiren. (Zeitschr. f. wissensch. zool., 1866, v. 16, p. 133–134.)

There is little need of comment upon Fischer's classification of scales of coleoptera into conchiform scales (Muschelschuppen), metallic scales (Metallblattschuppen), granulated scales (Granulationsschuppen), piliferous and shaggy scales (Haar- und Zottenschuppen) and fibrous scales (Faserschuppen). Leydig, as quoted above, destroyed the value of the division of granulated scales, and I have found that the division of fibrous scales owes its origin to what Fischer would call "granulations," that is to air-spaces, only that, in this case the granulations are arranged longitudinally in stripes. I can present no new classification of scales, if such a classification is possible, without studying more forms.

Before concluding this paper I will add a note on the mode which I have employed to gather scales, and some other minute objects of like nature, together upon one place on a microscope slide. The process consists in putting the scales in a drop of some quickly evaporating substance — chloroform is best for most purposes — on the slides. The scales will form in a kind of whirlpool, nearly all the scales finally settling down, as the liquid evaporates, in one place on the slide. Rapping the slide gently sometimes aids in the collecting together of the scales, and the tip of the scalpel used to scrape the scales from the insect can be washed in the drop of chloriform, thus saving every scale when they are from a rare specimen from which one desires to remove only a few scales. By inclining the slide gently, the mass of floating scales can be made to settle on the exact centre of the glass. One part of Canada balsam added to several hundred parts of chloroform will cause the scales to stick firmly to the slide.

(To be continued by a notice of some literature seen since preparing the original paper.)

THE CLASSIFICATION OF THE TINEIDAE.

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My attention has just been called to an article by Mr. Grote in *Papilio*, vol. 3. On page 43 he writes "I do not wish to enter into an argument as to the best classification of the *tineidae*, but disagreeing with Mr. Chambers, I do not think any one would take *Anaphora* for any thing but a tineid :" and on page 38 he writes, "So far as I have studied them we appear to be able to classify our moths under *sphingidae—tineidae*", &c., &c., naming the families usually adopted. I refer to this subject because the first of these above-quoted passages conveys the impression that I have stated that *Anaphora* ought to be placed elsewhere than in *tineidae*, and because the second quotation gives me an opportunity to write more fully than I have elsewhere done as to the classification of the *tineidae*; an opportunity that I desire because two such distinguished entomologists as Lord Walsingham and Mr. Grote have, very courteously of course, taken me to task for the expression of opinions as to the classification of the *tineidae* which are by them considered more or less